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Liquid Cooling Quick Disconnects for AI Data Centers

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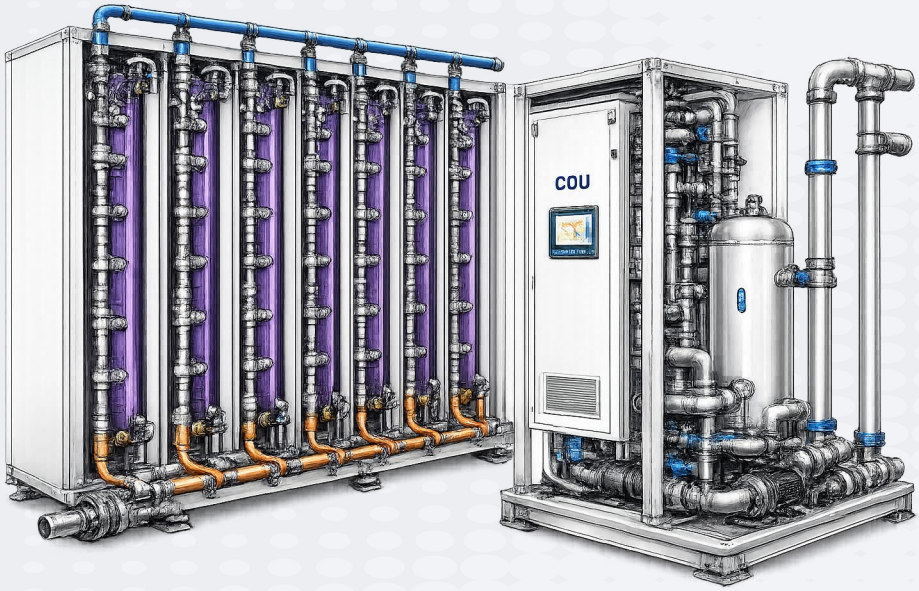
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EXECUTIVE SUMMARY



Artificial intelligence is accelerating the shift toward higher-density data center cooling architectures.

As rack power levels increase, liquid cooling is becoming more important in advanced compute environments where air cooling alone may not provide the required thermal performance.

Within these systems, liquid quick disconnects, or QDs, do more than move coolant from one point to another. Their design can affect flow restriction, coolant containment, blind-mate repeatability, service access, cleanliness control, and long-term maintainability across the cooling loop.

This whitepaper outlines key engineering considerations for selecting QDs in AI data center liquid cooling applications. It focuses on where QDs are used, what performance factors engineers should evaluate, and how connector selection should align with the broader cooling architecture, including cold plates, compact tray-level systems, rack manifolds, coolant distribution units, source-line infrastructure, hose assemblies, and custom manifold solutions.

Key Takeaway

In high-density liquid-cooled systems, QD selection should be evaluated as part of the full coolant path, with attention to flow performance, sealing behavior, blind-mate tolerance, serviceability, cleanliness, and system-level integration.

The Shift to Higher-Density Cooling Architectures

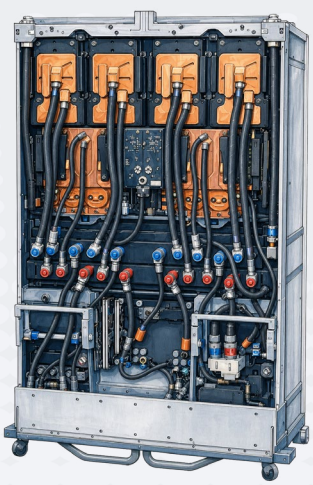
As AI compute platforms increase rack-level power density, cooling architectures are shifting from traditional air-cooled designs toward liquid-cooled systems that can support higher thermal loads in a compact footprint.

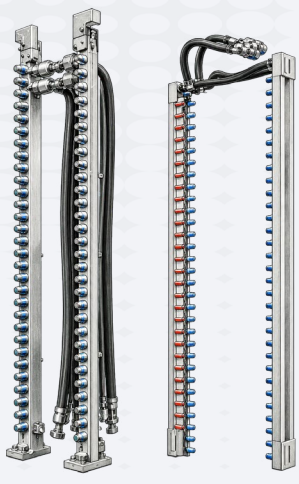
This shift changes the requirements placed on interconnect hardware. Cooling loops must support higher flow demand, tighter packaging, repeated service access, and reliable performance across multiple connection points.

In this environment, a liquid cooling QD should be evaluated as part of the full thermal and mechanical architecture, including cold plates, tray-level systems, blind-mate rack interfaces, rear manifolds, hose assemblies, coolant distribution units, and source-line infrastructure.

Amphenol Industrial Operations supports these architectures through liquid cooling QD families, hose assembly capability, and custom manifold solutions designed to align with different points in the cooling loop.

TRAY/COLD PLATE CONNECTIONS	RACK/MODULAR INTERFACES	CDU/SOURCE-LINE INFRASTRUCTURE
MQD	UQD/UQDB Rev. 2.0 BMQC	LQC & SHQD







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Where Quick Disconnects Matter Most in the Cooling Loop

QDs used in data center liquid cooling do not all serve the same role. Application position matters. A compact tray-level interface may prioritize packaging and service access, while a rack-level blind-mate interface may prioritize alignment tolerance and repeatable engagement.

Larger-format connections used at the CDU, manifold, or source-line level may place more emphasis on flow capacity, secure retention, dry-break behavior, and service safety.

The table below provides an initial mapping of QD families to cooling-loop locations. The specifications shown should be reviewed in context with the full system pressure budget, service model, and installation requirements.

Product Series	Primary Application	Defining Features	Flow/Pressure Data
MQD	Server Tray/Cold plate	Compact size, serviceability straight and right-angle versions	C_V:-02 = >0.4; -03 = >0.7; -04 =>1.4
UQD/UQDB Rev. 2.0	Blind-mate rack insertion	Standardized quick disconnect, low fluid loss	C_V: 3.6; rated flow: up to 17.79 L/min for -08
BMQC	Rack manifold/manifold connection	Alignment tolerance, repeatable engagement	C_v: 2.7 to 1.32; rated flow: up to 10 L/min
LQC	CDU/larger manifold connection	Larger flow, secure retention	C_v: 22; rated flow: up to 120 L/min
SHQD	Source line/full-flow infrastructure	Full flow, interlock safety, second-source support	C_v by size: 1 in. = 30; 1.5 in. = 90; 2 in. = 136
OMQD	Optical Module Cooling	Small form factor blind mate	N/A
Custom Manifolds	Customized Coolant Distribution	Multi-channel routing, integrated QDs/sensors	Application specific

Selection principle
Connector choice should be based on cooling-loop location, service conditions, flow demand, alignment requirements, and installation method, not nominal size or historical preference alone

Pressure Drop, Flow Consistency, and System Pressure Budget

Pressure drop is a key engineering consideration in liquid-cooled systems. Excessive restriction across a QD can reduce available coolant flow to downstream components and may contribute to imbalance across parallel paths in manifolded systems.

In high-density architectures, QD design should be evaluated as part of the total coolant path. Internal geometry, sealing approach, actuation mechanism, and flow-path design can all influence how the connector performs under application conditions.

Engineers should review the QD's contribution to the system pressure budget and compare available flow, Cv, pressure, and fluid-loss data against the intended cooling architecture.

Public product data provides a starting point for comparing liquid cooling QD families by flow capacity, Cv, operating pressure, burst/safe pressure, fluid loss, and service-cycle expectations.

Product Family	Public Flow/Pressure Reference	Key Performance Specifications	Application Context
MQD	Public flow-rate-vs-resistance curve available	C_V: 02 => 0.4; 03 => 0.7; 04 => 1.4 **Working Pressure:** 0-1 MPa **Safe Pressure:** 2 MPa	Compact tray applications; straight and right angle versions available
UQD Rev 2.0	Rated flow up to 17.79 L/min	C_V: up to 5.1 **Maximum Operating Pressure:** 0-100 psi **Minimum Burst Pressure:** 300 psi **Coupling Cycles:** minimum 5,000	Standardized quick disconnect for modular liquid cooling loops
UQDB Rev 2.0	Rated flow up to 17.79 L/min	C_V: up to 4.9 **Maximum Operating Pressure:** 0-100 psi **Minimum Burst Pressure:** 300 psi **Radial tolerance:** 1.0 mm (+0.3/0) **Coupling Cycles:** minimum 5,000	Blind-mate interface for rack/ server insertion
LQC	Public flow-rate-vs-resistance curve available	**Working Pressure:** 0-1 MPa **Safe Pressure:** 2 MPa **Fluid Loss:** <0.005 cc at 0.3 MPa	Larger-format quick disconnect for CDU/manifold applications
BMQC	Public flow-rate-vs-resistance curve available	C_V: 1.32* **Fluid Loss:** 0.025 ml **Working pressure:** 0-0.35 MPa **Radial Tolerance:** ±5 mm **Angular tolerance:** ± 2.7°	Blind-mate rack interface / ORV3 environment
SHQD	C_V values available by connector size	C_V: 1 in. = 30; 1.5 in. = 90; 2 in. = 136 **Working Pressure:** 0-1 MPa **Safe Pressure:** 2 MPa	Source-line/full-flow infrastructure; dual interlock safety

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Blind-Mate Performance and Installation Reliability

Blind-mate interfaces are increasingly important in rack-level liquid cooling architectures where service efficiency, alignment tolerance, and repeatable engagement are critical.

As server racks, trays, and manifolds are manufactured by different suppliers, tolerance stack-up can affect installation consistency. Over time, repeated service events may also introduce wear or alignment variation. For this reason, blind-mate QDs should be evaluated for radial tolerance, angular tolerance, engagement behavior, overstroke management, and service-friendly form factor.

Poor blind-mate performance can lead to installation difficulty, inconsistent engagement, premature wear, and increased service complexity in tightly packaged hardware.

Engineers evaluating blind-mate interfaces should consider the intended service environment, available installation clearance, alignment tolerance, and the role each QD plays within the cooling architecture.

Product Series	Radial Misalignment	Angular Misalignment	Positioning
UQDB Rev 2.0	1.0 mm	N/A	Blind-mate rack/server insertion
BMQC	±5 mm	**±.2.7°**	ORV3 blind-mate environments
OMQD	0.5 mm	N/A	Optical module cooling

Blind-mate tolerance should be evaluated in the context of the actual service and installation environment.

Cleanliness, Contamination Control, and Traceability

Cleanliness and traceability are important considerations in liquid cooling systems, particularly where small flow passages and tightly managed thermal performance can increase sensitivity to contamination.

While QDs do not actively filter or remove contaminants from the cooling system, the connector, assembly process, packaging method, and handling practices should be evaluated to ensure they do not introduce unnecessary contamination risk.

Amphenol Industrial Operations liquid cooling QD families include traceability features that can support product identification, documentation review, and issue investigation if required. Confirmed cleanliness, packaging, and inspection details should be evaluated as part of the overall system qualification process.

At the system level, cleanliness controls and traceability can help support deployment readiness, fluid-system reliability, and faster issue review during qualification or field support.

Evaluation Area	Why It Matters
Cleanliness Approach	**QDs are assembled and packaged in an ISO 9 cleanroom**
Traceability	**QDs include laser-etched QR-code traceability where applicable**
Documentation	**QDs can be traced to raw materials, manufacturing equipment, assembly, and packaging**
Benefits	Cleanliness controls can support deployment readiness, fluid-system reliability, and faster issue review during qualification or field support

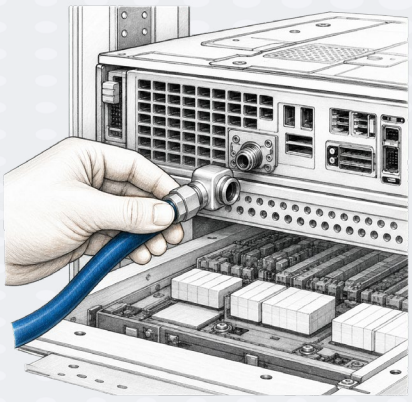
Risk reduction principle
Cleanliness controls, packaging practices, and traceability records can help reduce deployment risk and support faster issue review if a system issue occurs.

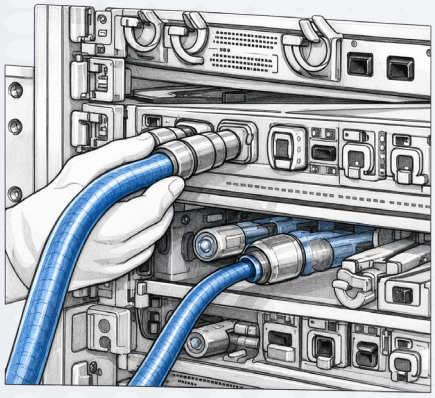
Serviceability in Dense Hardware Environments

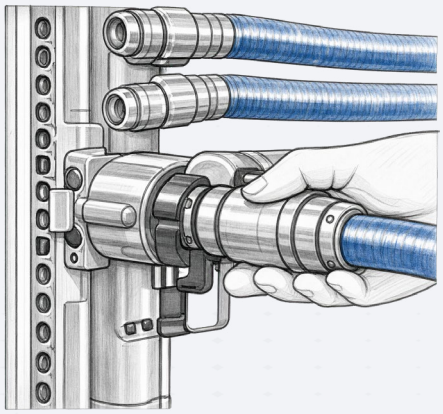
Serviceability is a practical design consideration in dense liquid-cooled hardware environments. Hand clearance, hose routing, pressurized lines, and planned hardware replacement can all affect how easily a QD can be accessed, connected, disconnected, and serviced.

In these applications, QD selection should account for connection style, available access space, disconnect behavior, and the expected maintenance process. Compact tray-level connectors, blind-mate interfaces, and larger source-line connections each support different service requirements.

Engineers should evaluate serviceability alongside flow performance, sealing behavior, and installation repeatability to ensure the selected QD aligns with the intended cooling architecture and maintenance approach.







MQD	UQD/UQDB Rev. 2.0	SHQD
Compact footprint for tray-level access	Manual UQD connection or blind-mate UQDB engagement for repeatable service access	Dual interlock dry-break for maintenance-sensitive service

Field Reality
A QD that performs well on paper but is difficult to access, connect, or disconnect in a dense rack environment can increase maintenance complexity and service risk.

Product Family Selection by Application

Different QD families support different roles within a liquid cooling architecture. Selection should be based on application position, service method, flow requirement, blind-mate needs, packaging constraints, and the intended maintenance approach.

The table below provides a practical starting point for matching each product family to the application conditions where it is most likely to be considered. Final selection should be validated against the system pressure budget, coolant requirements, installation method, and qualification criteria.

Product Series	Best-Fit Application	Why an Engineer Would Consider It
UQD	Manual quick disconnect in modular liquid cooling loops	Standardized quick disconnect performance for general liquid cooling interfaces
UQDB	Blind-mate rack/server interfaces	Self-alignment and blind-mate functionality for repeatable rack-level insertion
UQD/UQDB Rev 2.0	Updated OCP-aligned modular platform	Improved flow, more defined geometry, and manufacturer cross compatibility
BMQC	ORV3 blind-mate manifold/ rack environments	Wider blind-mate tolerance and window with ±5 mm radial and ±2.7° angular capability
MQD	Compact computer tray/space-constrained applications	Small form factor and push-pull quick disconnect design
LQC	CDU/inlets/manifold connections	Thread-to-connect design for larger-format cooling interfaces and OCP-inspired applications
SHQD	Source line/full-flow infrastructure	Dual interlock safety and Dual-interlock safety with size-specific C_V values for full-flow source-line applications
OMQD	Optical module cooling	1 mm fluid diameter and compact blind-mate design for tight optical cooling applications
Custom Manifold	Coolant distribution and integrated routing	Multi-channel architecture with custom routing, QD integration, and sensor support

Selection guidance

Product family selection should connect the application location to measurable requirements such as flow capacity, pressure rating, fluid loss, alignment tolerance, mating cycles, and service access.

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Beyond the QD: Integrated Assemblies, Hose Solutions, and Manifolds

In many liquid cooling applications, engineers are evaluating more than the QD alone. They are considering how the connector works within a broader system that may include hose assemblies, manifolds, fittings, sensors, routing constraints, and customer-specific packaging requirements.

Integrated assemblies and custom manifolds can help reduce installation variability, simplify sourcing, and improve repeatability across deployments. By evaluating the QD, tubing, manifold, and sensor strategy together, engineers can better align the interconnect solution with the intended cooling architecture, packaging envelope, and service approach.

Amphenol Industrial Operations supports liquid cooling system integration through custom manifold development, material selection, design and simulation support, and validation activities related to pressure, thermal, flow, and corrosion requirements.

System Element	Engineering Benefit
Pre-Configured Hose Assembly	Reduces Field Assembly Complexity and Supports More Repeatable Installation
Hybrid Tubing Options	Supports Material and Fluid Compatibility Flexibility
Manifold Integration	Improves System Coordination, Packaging, and Coolant Distribution
Design and Simulation	Supports Reliability Analysis and Alignment with Thermal Architecture
Pressure/Thermal/Flow Validation	Supports Pressure, Thermal, and Flow Validation against Application Requirements
Integrated QDs and Sensors	Supports Application-Specific Routing, Monitoring, and Connection Strategy
Custom Manifold Solutions	Enables Multi-Channel Architecture and Tailored System Layout

Systems View

System-level cooling performance depends on more than the QD alone. Connector, hose, manifold, routing, and service requirements should be evaluated together.

Qualification Checklist for Engineers

This checklist is intended to help engineers evaluate liquid cooling interconnects for data center and AI cooling architectures. Each item should be reviewed against the intended cooling loop, service model, installation method, coolant type, and operating conditions.

Public product data can provide a starting point for supplier screening, but final qualification should be matched to the specific architecture and application requirements.

Evaluation Item	Why It Matters
Operating Pressure	Confirms fit for the intended operating environment
Burst/Safe Pressure	Supports pressure margin and deployment confidence
Rated Flow	Helps align connector choice with coolant-path demand
CV/Flow Efficiency	Supports flow budget and pressure-drop review
Fluid Loss	Affects Service Cleanliness and Maintenance Readiness
Mating Force	Influences Usability and Insertion Behavior
Coupling Cycles	Indicates Long-Term Service Readiness
Blind-Mate Tolerance	Supports Installation Repeatability in Constrained Hardware
Applicable Coolant	Confirms Baseline Fluid Compatibility
Temperature Range	Confirms Fit with Operating Service Conditions
Shell and Seal Material	Supports Material Compatibility Review
Termination Type	Helps Match Connector to Manifold, Tube, Hose, or Source-Line Interface
Application Fit/Standards Alignment	Confirms Alignment with Applicable Standards and Application-Specific Requirements

Practical takeaway

Qualification should connect catalog specifications to the real system requirements of the cooling loop, including flow, pressure, service access, coolant compatibility, and installation conditions.

Conclusion

As liquid cooling expands across AI and high-density compute platforms, QD selection should be evaluated as part of the full cooling architecture. Flow behavior, blind-mate repeatability, fluid containment, cleanliness, traceability, material compatibility, and service access can all influence long-term system performance.

Amphenol Industrial Operations supports liquid cooling architectures with compact tray-level QDs, blind-mate rack interfaces, source-line interconnects, hose assemblies, and custom manifold solutions. By evaluating interconnects in the context of the full coolant path, engineers can better align product selection with flow requirements, service conditions, installation method, and platform architecture.

Final takeaway
QD selection should be based on measurable system requirements, including flow demand, pressure rating, fluid loss, blind-mate tolerance, service access, coolant compatibility, and qualification needs.

For technical consultation regarding liquid cooling interconnect selection, blind-mate architecture, manifold integration, or application support, contact:

Jensen Stenberg
Field Application Engineer
Liquid Cooling & Power to Board
Jstenberg@amphenol-aio.com

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Amphenol Industrial Operations Consolidated (AIOC) provides interconnect solutions for demanding industrial and high-performance applications, including data center power and liquid cooling systems. AIOC's liquid cooling resources span compact tray-level connectors, blind-mate rack interfaces, source-line interconnects, hose assemblies, and custom manifold solutions, supporting cooling architectures from localized service points to larger rack-level, CDU, and facility infrastructure connections.

With factories supporting global interconnect and liquid cooling solutions across New York, Arizona, Mexico, China, Hungary, Türkiye, and India, AIOC combines engineering, manufacturing, and application support across a broad international footprint. Capabilities include precision machining, plating, injection molding, assembly, and support for high-power, high-density, and harsh-environment applications.

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